

Testing Ultracapacitors



Sandia National Laboratories' Power Source Engineering Dept.

**Tom Hund, Nancy Clark, Wes Baca, Carla Tatum
Ganesan Nagasubramanian, and David Ingersoll
November, 2002**

Funded by the DOE Energy Storage Program

[←Home](#)

[←Agenda](#)

ESSP02, 2002 6/16/2003

1



Testing Ultracapacitors

- What is an Ultracapacitor?
- Introduction
- Ultracapacitor Applications
- Ultracapacitor Testing Issues
- Test Results
- Summary

What is an Ultracapacitor?

■ Electrochemical Capacitor (EC)

- A device which accumulates electrical charge in the double layer, which is formed between an electron conducting surface and an electrolyte usually potassium hydroxide.
- EC is usually made with porous high surface area carbon (*2,000 m²/g, carbon electrode could contain 60 – 360 F/cm³*)
- Distance between plates is several angstroms

Introduction

- **Ultracapacitors may:**
 - be more reliable
 - require lower maintenance
 - have a much greater cycle-life
 - have a lower life-cycle cost than batteries

Ultracapacitor Applications

- 
- **Power Quality Systems**
 - **UPS Systems**
 - **Hybrid Electric Vehicles**
 - **Stand-Alone Fuel Cell Systems**
 - **Stand-Alone Micro Turbines**

Ultracapacitor Energy Storage

Parameter	Typical Capacitors	Electrochemical Capacitors	Batteries
Time Constant (sec)	<0.1	0.2 - 10	>100
Energy Density (kJ/kg)	0.1 - 0.5	0.5 - 20	>100
Power Density (kW/kg)	>10	~0.5 - 1	~0.2
Cycle-Life (cycles)	>1,000,000	>100,000?	<1,500

Source: EPRI PEAC, ESMA Ultracapacitors, and HILTech Super Capacitors

ESMA Ultracapacitor

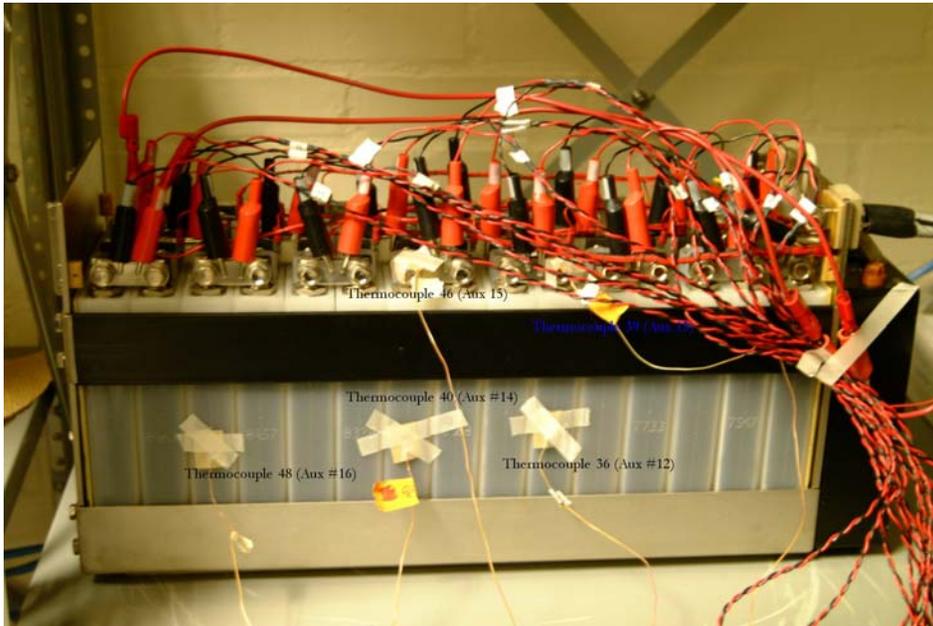
- **Electrochemical Aqueous Asymmetrical Design (Type III)**
 - Negative electrode is made of activated carbon
 - Positive electrode is made of nickel hydroxide
 - Asymmetrical design provides 4 to 5 times more energy storage over carbon/carbon symmetrical design
 - Max operating voltage is 1.3 to 1.6 V

ESMA Has Concerns With Sandia's Test Procedures

- Sandia subjected ESMA capacitors to abusive conditions by continuously cycling at 10-, 40-, 50-, and 70-amps
- The test results are a result of continuous cycling and the resulting cell temperatures, approaching 50C, which could damage cells
- ESMA recommends cycle rate, 3-cycles/hr
- Capacitors designed for float/SLI operation only

Testing

ESMA Ultracapacitor and Experimental PEAC PQ System



Background

- Evaluate the capabilities of the EPRI PEAC power quality (PQ) system
 - Test the EPRI PEAC ultracapacitor PQ system that was designed to provide transient surge capability for a stand-alone micro turbine
 - System Specs
 - » Module rating - Capacitance/Energy = 330 F / 220 kJ (30-cell per module, 21 to 42 V)
 - » 9 modules per rack
 - » 189- to 378-volts per rack
 - » ~550 Wh per rack
 - » System rated at up to 200 A current, 75.6 kW
 - » Module rated at up to 50 A current, 18.9 kW

Ultracapacitor Testing Issues

■ Cell Voltage

- How well can cell voltage be managed?
- Do module and cell leveling circuits work in float service?
- Does “Equalizing” cells periodically work in cycling applications?

■ Cell Temperature

- How do you control heat from charge and discharge cycles?
- What duty-cycle and/or rate is required for temperature control

ESMA Test Results

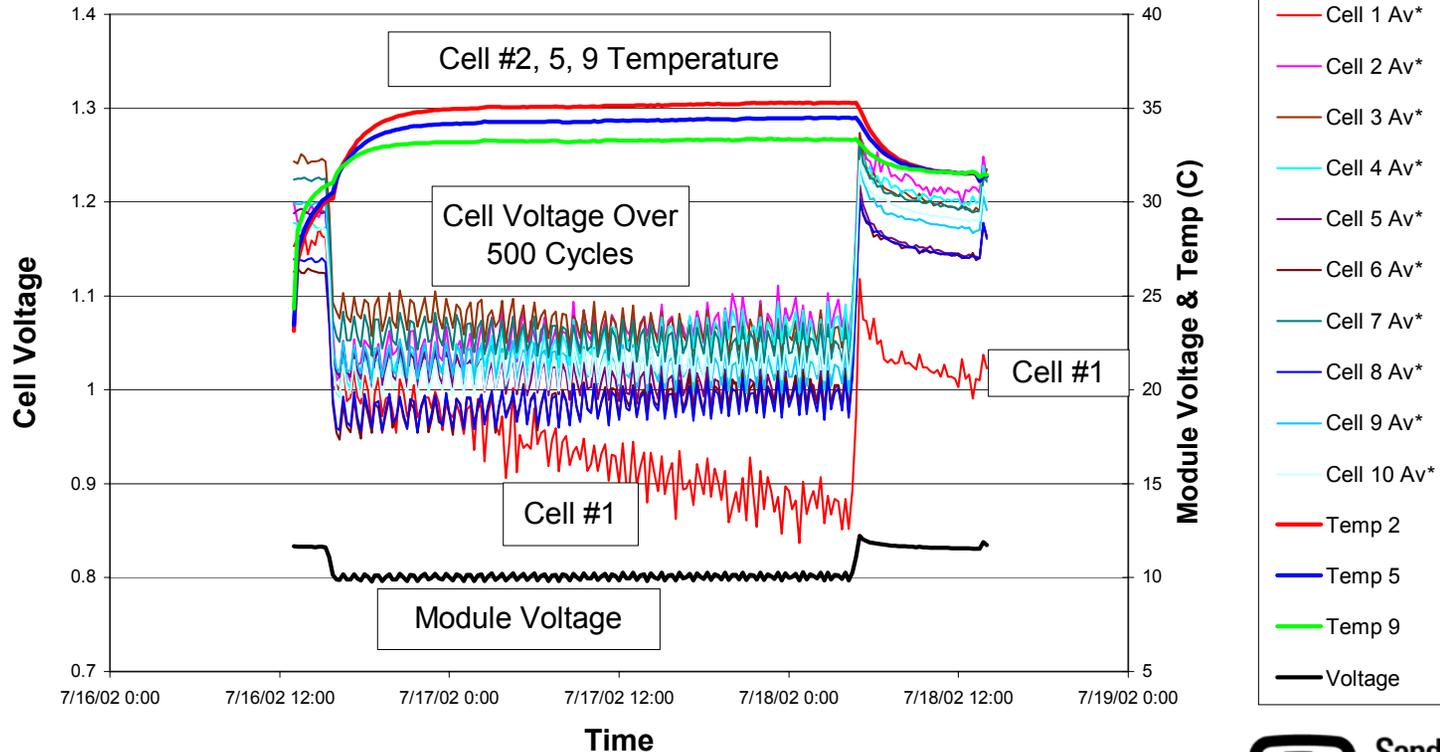
Super Cap Cycle Test

10EC402.2-60-13/6.5-.003

40-amps Charge/Discharge

SCAP40A-2

7/18/02



ESMA Test Results

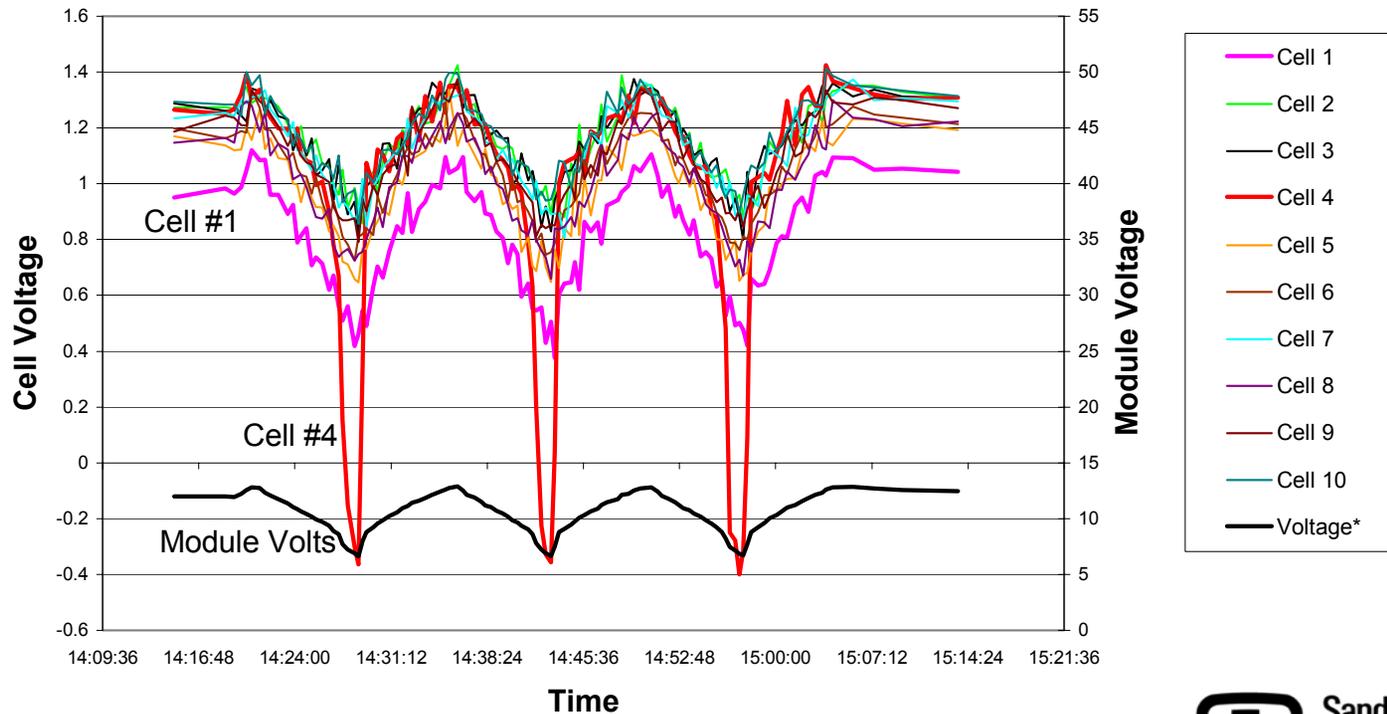
Super Cap Cycle Test

10EC402.2-60-13/6.5-.003

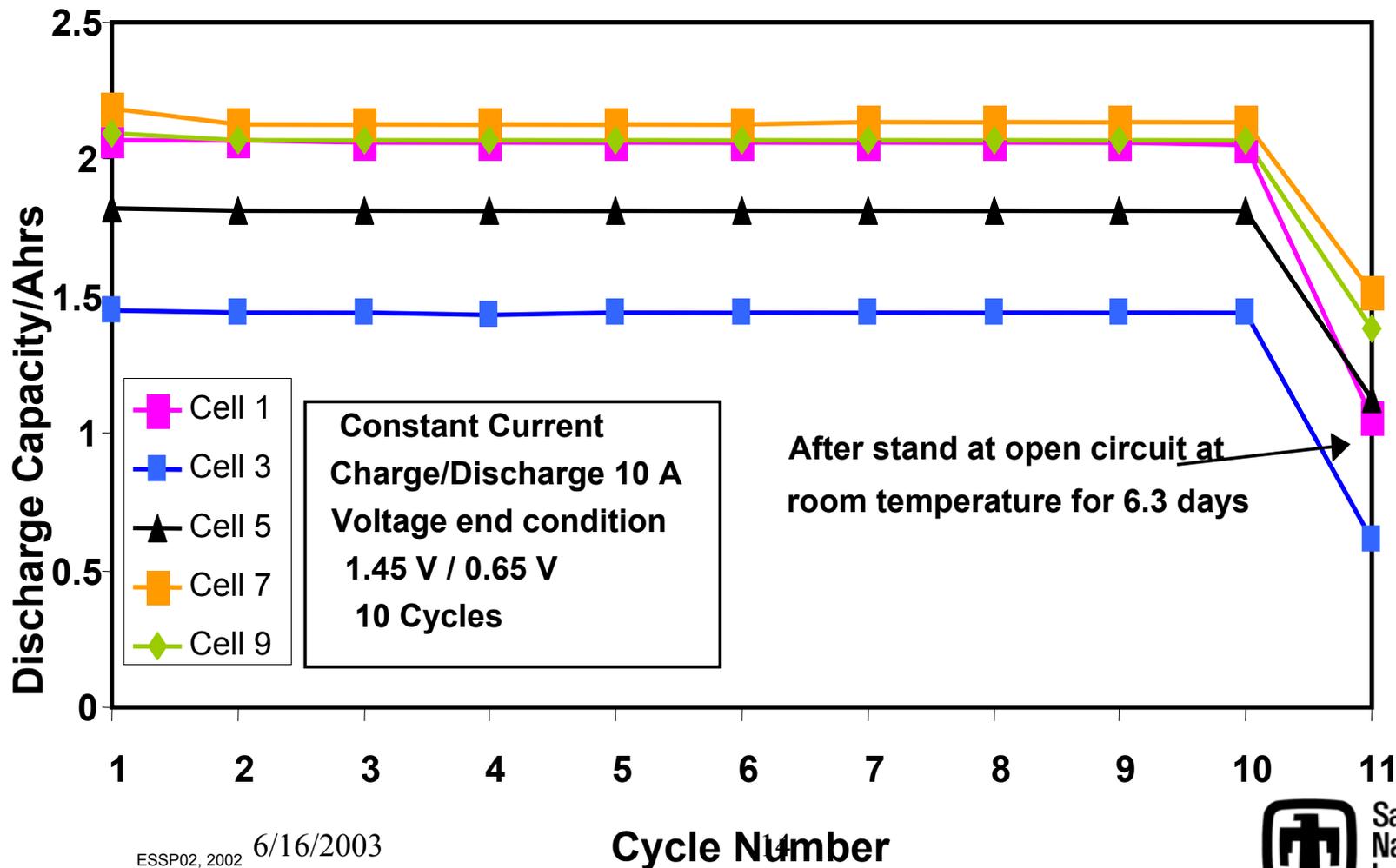
10-amps Charge/Discharge

SCAP40A-7

7/24/02

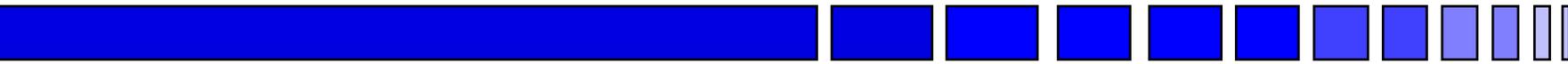


Discharge Capacity as a Function of Cycle Number for Five of the Cells Making up ESMA 10EC402 Capacitor

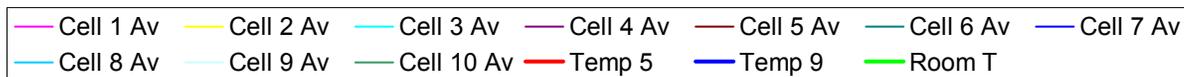
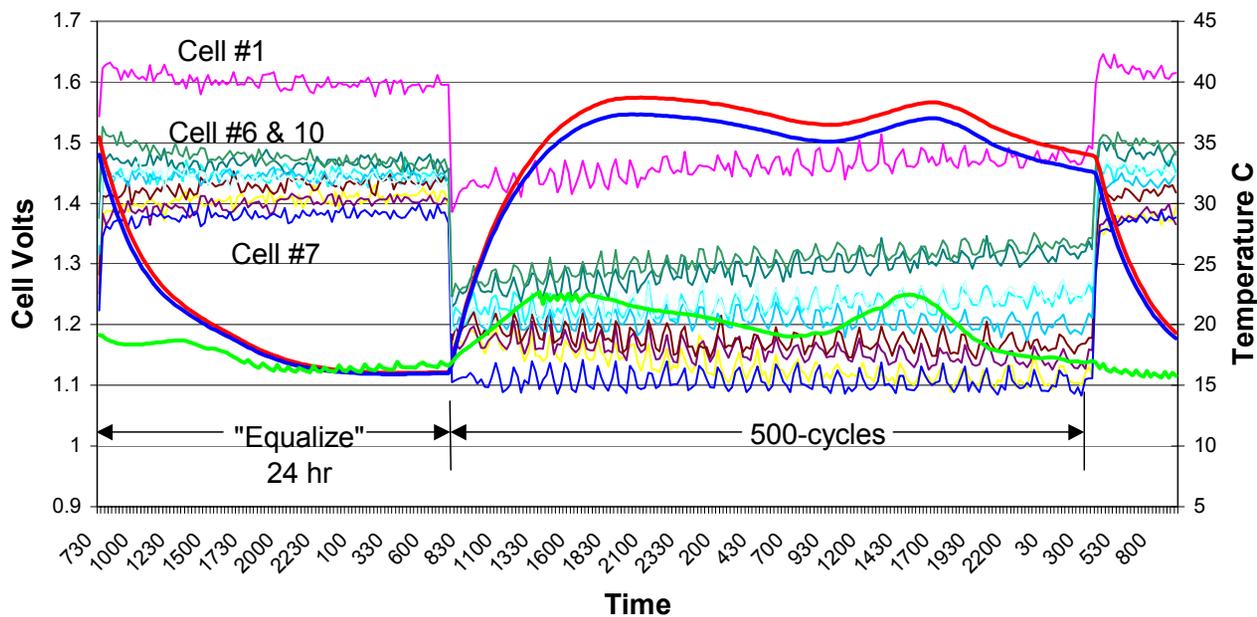


Test Results

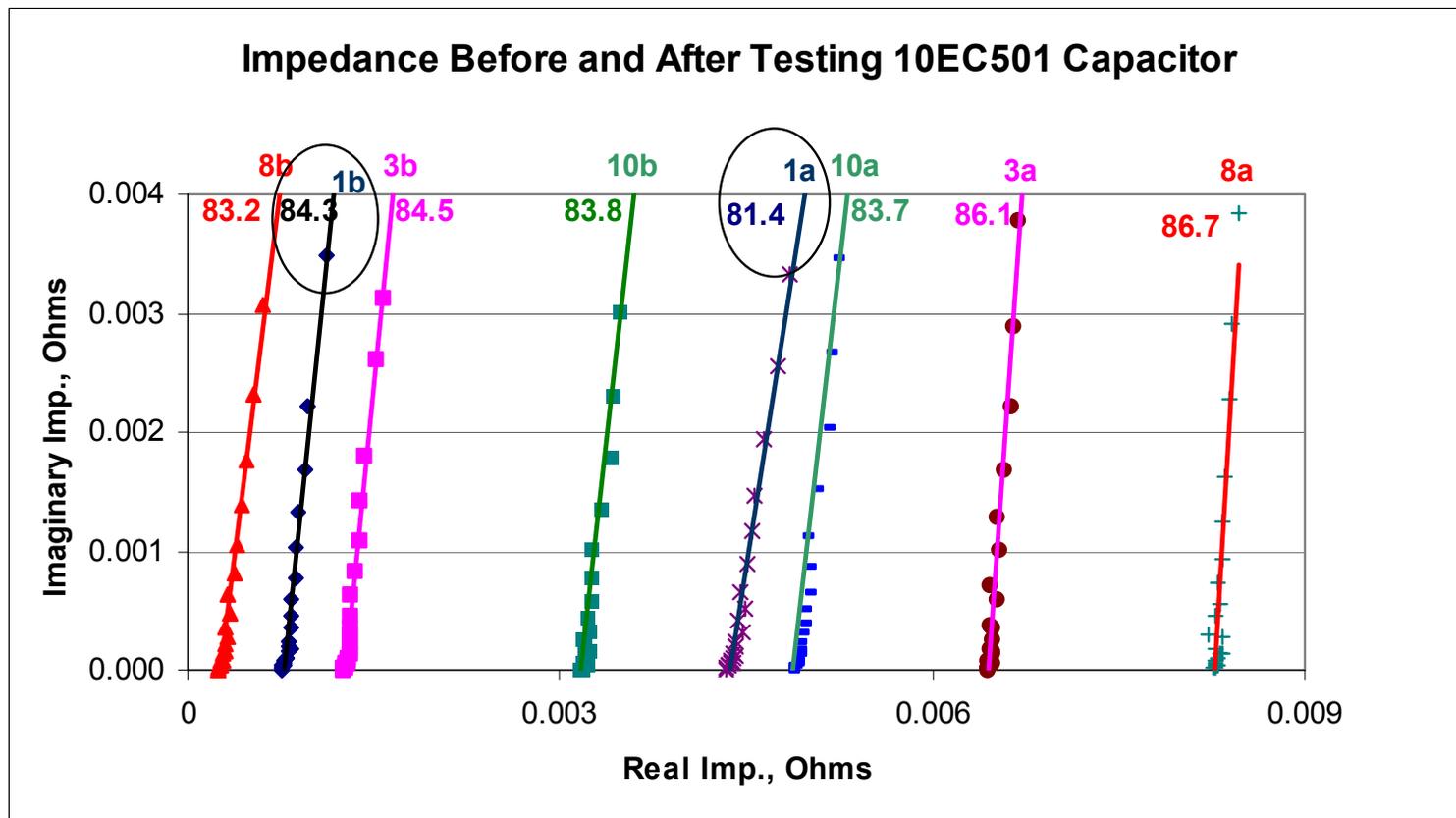
“Equalize”, Cell Voltage, and 63% Duty Cycle



Ultracapacitor Cycle Test
10EC501-35-13/6.5-.003
40-amps Charge/Discharge and 24 hr "Equalize" At 1.45 vpc
11/6/02

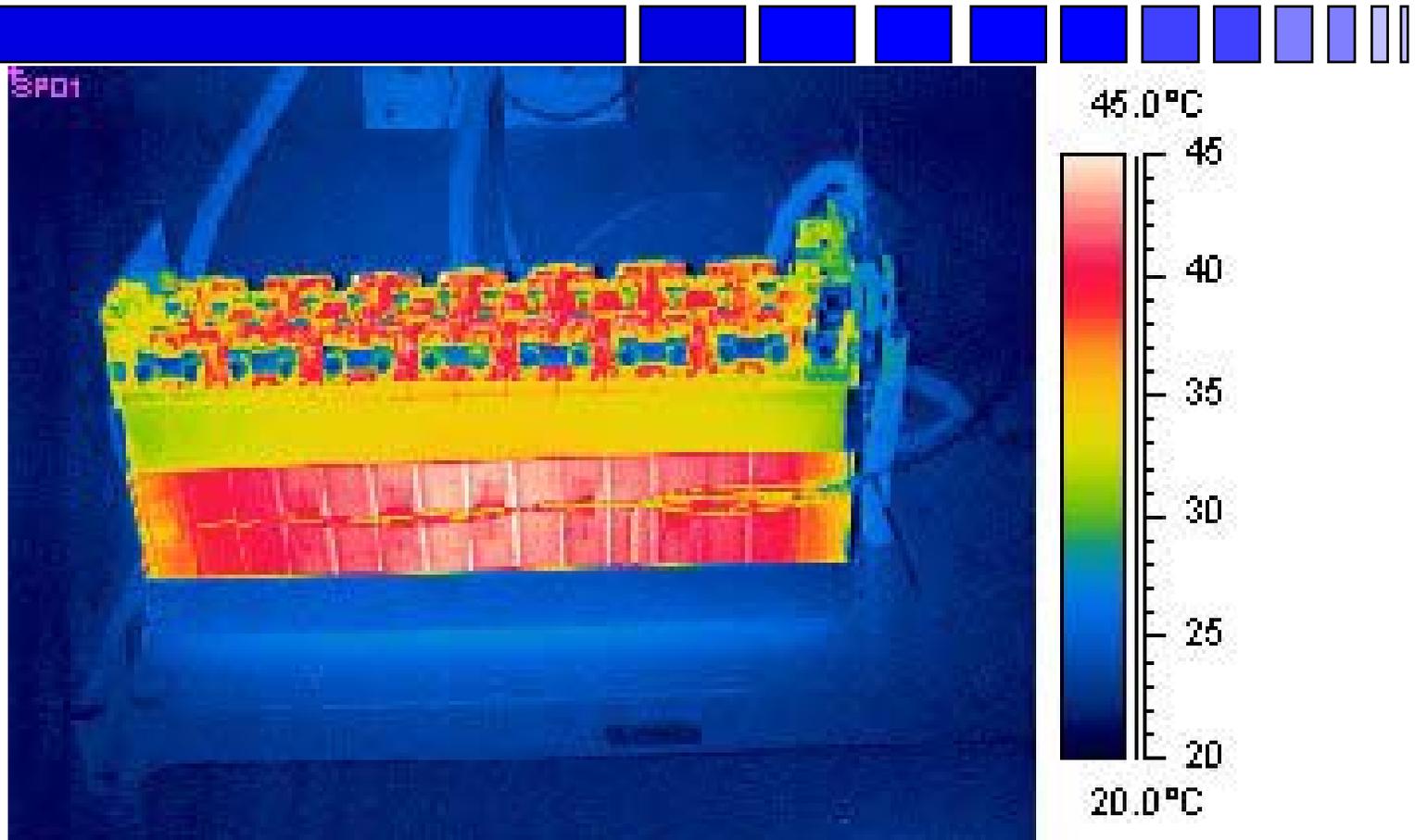


Impedance Test On 10EC501 Before (b) and After (a)



Test Results

IR Image of The 30EC402



Module IR Image from Cycle 50 at 70-amps

Summary

- 
- **Electrochemical Capacitors Have The Potential To Become A Reliable Energy Storage System**
 - **Work To Do**
 - Learn to manage cell voltage
 - Verify performance in high voltage strings
 - Identify appropriate management schemes
 - Refine and improve the technology